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EXPLORATORY STUDY OF THE ORGANIZATION AND MANAGEMENT OF HAZARD MITIGATION IN THE CIVIL AIR TRANSPORT SYSTEM

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This exploratory study suggests that organization and management principles and procedures for hazard mitigation derived from the long experience with this objective in the air civil transport system may prove of great value in the development of hazard mitigation activities associated with other major technological systems of national concern. Cited in the report are examples where difficulties may have already arisen from non-observance of some of these principles and where difficulties may arise in future endeavors if these principles are not observed.

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EXECUTIVE SUMMARY

The nation is facing the potential of increasing public hazards deriving from increasing need to apply sophisticated technology to solve national problems. Hazard mitigation efforts in the past have frequently been scattered through, and sometimes submerged in other national responsibilities. A recognition of this fact figured importantly in the recent establishment of FEMA.

One exceptional example of comprehensive focus on technologically based hazards is found in the explicit attention the federal government has given hazard mitigation in the civil air transport system. From the beginning of civilian air transport in the mid 1920's it was recognized as an inherently hazardous enterprise, and the government has maintained a focussed effort from the outset of this enterprise to mitigate the hazards. The success achieved in this endeavor would point to the existence of much experience of value to any national efforts to mitigate technologically based hazards.

A previous study by RANN, INC. examined this experience from the standpoint of its more general value in terms of technical, operational and legal principles and procedures which have evolved. It is the purpose of this paper to examine, from the same standpoint, the principles and procedures of organization and management which have evolved to achieve effective hazard mitigation through safety regulation of the civil air transport system.

It is noteworthy that these principles and procedures have (1) developed and applied safety regulations in a way to achieve widespread public confidence in the system to the degree that commercial air transport dominates over all other forms of commercial passenger transport in the U. S. today, and (2) contributed crucially to the development of an industry that employs about one million Americans and is the second largest among U. S. manufacturing employers, and which contributes more to the U. S. balance of trade than any other manufacturing industry.

Four basic organization and management principles underlie the success of hazard mitigation in the civil air transport system. First was the very early realization that this was a national problem where uniformity of applicable safety regulations and procedures throughout the system must be achieved. Second, was the recognition that the overall system was composed of many closely interacting subsystems, all of which must be under cognizance of a central authority to assure that regulation changes to mitigate hazards in one subsystem did not exacerbate hazards in related subsystems. Third, was the recognition

that if a highly regulated system was to maintain healthy growth, regulations must be developed with full and constant participation of all government regulatory elements, and of the industry being regulated. Finally, to enable these principles to be applied effectively to improve hazard mitigation, on a continuing basis, it was learned that thorough, constant and unbiased investigation and reporting of all incidents and accidents was required.

This exploratory study of organization and management in hazard mitigation in the air transport industry has served to highlight a number of additional principles which have contributed to the success achieved and which carry strong implications of transferability to hazard mitigation control of other technologically sophisticated systems. Some key examples of these principles are as follows:

1. The development of safety regulations and applications must be accepted as being constantly in a fluid state; the introduction of new technology does not allow for any certain degree of permanance in any regulatory stance.

2. While centralized oversight of safety regulations must exist, field operations closely involved with day-to-day surveillance of industry will also be required.

3. In addition, to apply safety regulations effectively, the vast number of technical aspects involved may well require specified industry employees in compliance oversight (i.e., officially designated employees of industry).

4. Capacity to rationally develop and apply regulations to technologically sophisticated operations is beyond that of any single group; cooperation and support from throughout government, industry and universities will be required and must be responsive and available.

5. The necessarily close association of the regulated industry and the regulating groups inevitably leads to questions broadly described as "conflict of interest". These questions can and must be resolved. To a major degree this has been achieved through establishment of an independent group assessing overall hazard mitigation effectiveness through independent accident and incident investigation.

6. In technological systems where human interaction with a machine occurs, the question of minimum level of safety, involving human training, design for gradual degradation of safety with malfunction (fail-soft), and acceptable warning of partial or potential failure must be kept foremost in mind and given constant attention.

7. The nature of advice by the regulatory group as to interpretations and demonstration of compliance with safety regulations will require close examination. If such advice is given in too precise detail industry development will be overly inhibited and the government will assume excessive responsibilty for hazard mitigation as compared to industry (this must be a shared responsibility). If advice is too imprecise, excessive effort will be devoted to reconciling many different interpretations and proposals for demonstrating compliance.

This exploratory study suggests that these and other organization and management principles and procedures for hazard mitigation derived from the long experience with this objective in the air civil transport system may prove of great value in the development of hazard mitigation activities associated with other major technological systems of national concern. Cited in the report are examples where difficulties may have already arisen from non-observance of some of these principles and where difficulties may arise in future endeavors if these principles of hazard mitigation are not observed.

Such endeavors may well include achieving the national goals for synthetic fuels production.

INTRODUCTION

The mitigation and control of an ever increasing number of technological hazards has become a major national challenge. As a consequence, wide ranging efforts are underway to find cost-effective means for combating and mitigating these hazards. Government, industry and universities are all involved in these efforts.

It has been pointed out in many places and many times that the air transport industry has faced major technical hazards and, on the whole, has been successful in overcoming them over the years.[1*] One special feature of this success is that it has been achieved in the face of required day-to-day operations where continued safety is essential to assure continued operational and economic viability of this industry. It is noteworthy too that these operations are carried out by large numbers of skilled personnel rather than by a relatively few hand-picked and specially trained professionals as is the case in some highly sophisticated and constrained technical operations such as manned space flight. Thus it is expected that the experience gained in achieving the high levels of safety characterizing air transport operations carries much information of value in the control and mitigation of hazards and disasters associated with other emerging technological activities of concern to FEMA.[2]

Examination of the aeronautical experience in relation to controlling other technological hazards and disasters is receiving increased attention.[3,4] To a large degree these examinations have

*All superscript numbers refer to references which are listed in the Appendix at the end of this report.

concentrated on technical actions which can be taken to control and mitigate hazards. Standard aeronautical developed techniques like design redundancy, quality control, new-technique validation, pre-disaster incident analysis, fault diagnoses and others have been studied with a view towards wider application. In addition, the role of the human in interacting with the machine has been given scrutiny in such activities as crew selection, training, simulation, information transfer, group management and interaction and stress overload. From these studies it is becoming clear that aeronautical experience has much of value to offer. The Three Mile Island incident has proved to be a powerful spur to further examination of these activities.

The problem of achieving a high degree of safety in air transport has a major feature in common with many of the hazard mitigation responsibilites of FEMA. It is a national, and indeed international problem which must be dealt with in a consistent way, yet be acceptable to a wide variety of industries involved. Thus, it is not acceptable to tailor basic safety control procedures to the peculiarities of any one or a few segments of the industry. The widespread nature of potential hazards associated with air transport also makes it a problem that is not amendable to differing management by local authorities. Varying organizations with differing managements and regulations would have prevented the development of the remarkably safe and successful system that now exists. It is not difficult to find similar challenges within FEMA's spectrum of hazard mitigation responsibilites. The production, transport, use and disposal of hazardous materials is a case that comes easily to mind.

While considerable attention is being paid to adapting aeronautical technical approaches to achieving improved safety in other hazardous technological activities, less attention is being paid to the potential application of organization and management principles that underlie this success, and to the economics that prescribed the fine balance that had to be reached to achieve both safety and enduring viability of the air transport system. As in the case of the strictly technical developments, these phases of the activity are constantly evolving with changes dictated by changing circumstances. Not the least value to be found in this experience is how the organization and management can respond to these required changes without serious disruption of on-going system operations.

It is the purpose of this paper to examine the development of the organization and management system to mitigate hazards in the civil air transport system. The basic system framework in the federal government will first be described along with the changes leading to the present form. Attention will be paid not only to the actual changes but also to the compromises that had to be reached between opposing forces as each change evolved. Special consideration will then be given to the organization and management of the Federal Aviation Administration (FAA) which has the lead federal responsibility today for hazard mitigation. This is followed with an examination of the role of government agencies, universities and industry in hazard mitigation. Finally, selected issues and principles, and some implications as to the broader application of the organization and management experience in hazard mitigation for civil air transportation will be considered.

DEVELOPMENT OF THE FEDERAL ORGANIZATION AND MANAGEMENT SYSTEM

The federal organization and management system of today for hazard mitigation in civil air transportation is highly sophisticated and the product of many years of development. The sequence of events that highlighted this development is worthy of examination to clarify the causes thereof and the basic principles which evolved in the process. A summary of these events as they occurred beginning with the establishment of the Aviation Branch of the Department of Commerce in 1926 is shown in Figure 1.[5,6,7]

Prior to this establishment and following World War I, the military departments of the federal government were the principal sponsors of aviation development to strengthen the key role aviation would have in any future military events. The federal government, through the military departments and the National Advisory Committee for Aeronautics (NACA), supported new technical developments and provided a reservoir of trained airmen. To guarantee the airworthiness of new aircraft the government purchased, the military also initiated the development of a set of military specifications that manufacturers had to meet. These specifications defined the design, construction and performance standards which "assured" that the aircraft not only met military performance requirements but also achieved an acceptable level of flight safety.

Spurred on by European commercial activities, where modified versions of bombers were introduced as commercial transports, American entrepreneurs undertook similar activities. Thus, by the mid-1920's the first evidences of commercial air transportation began to emerge from widespread "barnstorming" activities in the U. S. The federal government, also spurred by a desire not to lag behind foreign developments, entered the commercial air transport field in 1926. Thus. on May 26, President Coolidge signed the AIR Commerce Act of 1926.[8] Under this Act the Secretary of Commerce was instructed to:

1) Foster air commerce
2) Designate and establish air ways
3) Establish, operate and maintain aids to air navigation
4) Arrange for R&D to improve such aids
5) License pilots
6) Issue airworthiness certificates for aircraft and major aircraft components
7) Investigate accidents

A new Assistant Secretary of Commerce was established to meet these goals and the Aviation Branch of the Department was formed thereunder. The first air commerce regulations became effective on December 31, 1926.

Several basic principles were established through this Act which remain in force today and which have been the subject of continuing review. Perhaps the most significant is that air commerce was recognized as an inherently hazardous enterprise which should be underfederal regulation for safety, with every essential, active participant subject to uniform federal regulation. Now for a period of time, regulation of airports and airport operations remained a local option, usually public and in a few cases private, but regulation of these activities too was finally taken over by the federal government through the Federal Aid to Airport Program. The key reason for this step, of course, was recognition of the requirement for uniform regulation of the organization and management procedures for control of the airways and associated ground support equipment. The potential confusion and hazards, to operating aircraft and exposed surroundings, of permitting non-uniform procedures in different airport systems was deemed unacceptable.

Another principle, one of equal interest here, was the recognition that only through focussed responsibility and management could the safety of the air-transport-using-public be protected. Up to this point, the public protection had been dependent largely on the need of manufacturers and operators to maintain a reputation for safety to sell their product and service. With this Act the lead responsibility to the public, <u>for safety</u>, was focussed in the hands of the federal government. This was precedent setting at the time although it is becoming more prevalent as technological hazard awareness increases.

Also of interest is the fact that the responsibilites of the Secretary of Commerce included both the fostering of air commerce and its regulation for safety. This principle has remained and has been the subject of continuous debate since, clearly, these two responsibilities can come into conflict.* The issue has tended to spread into other technologies of national concern where technical development is accompanied by increased hazard.

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*Early recognition of this appears in the formation of a separate Accident Investigation Board in DOC in 1928. See Figure 1.

On June 21, 1938, President Roosevelt signed the Civil Aeronautics Act. Under this Act federal government oversight of all non-military aviation was coordinated under the new Civil Aeronautics Authority (CAA) separated from the Department of Commerce (DOC). This action was taken in recognition of the rapid growth in civil air transport and need for explicit attention not possible at that time within the myriad activities of the DOC; the question of immediate public safety loomed large in this decision.

The CAA was given the same responsibilities carried by the DOC but in addition was made responsible for achieving safe and efficient operation of airports, whether these were local public or private activities. In effect, certification of airports and their operation became a new and major activity of the new Authority. At the same time an Air Safety Board was established to investigate accidents, determine probable cause and make recommendations for action to prevent recurrence. Thus, recognition was given to the conflict between regulation for safety and promotion of air commerce on the one hand, and the responsibility for accident investigation to assign cause, whether private or federal in nature.

In 1940 Roosevelt reorganized the role of the Federal government in air transport. The responsibilities of sponsoring growth, including certifying to acceptable standards the various systems elements and developing and operating the airways, was once again placed under the Department of Commerce in the new Civil Aviation Administration (CAA).

The responsibility for economic rule making, adjudicating and for investigating accidents (and assigning cause) was under a Civil Aeronautics Board (CAB), a five-man board, named by the President and reporting directly to him.

By the end of WW II, aviation had made major technical advances. Military transports and bombers laid the technology for production of commercial transports that could fill a major need in long range high speed transportation. Vastly increased business and political interactions within the U. S. and between the U. S. and Europe provided the potential for a major expansion in commercial air transport. Recognition of this potential and its importance to national interests led to a number of federally sponsored studies regarding appropriate federal actions to be taken. President Truman created an Air Policy Commission to investigate national policies (Survival in Air Age, the Finletter Report, January 1948). On March 1, 1948 the Congressional Aviation Policy Board (Brewster Board) released its report recommending government action and reorganization regarding aviation. The Hoover Commission on government reorganization submitted to Congress several recommendations relating to the government's role in civil aviation, and on September 30, 1950 Truman approved the Prototype Aircraft Act (P.L. 81-867) which would have found the government supporting the development of new civil aircraft. Little action resulted from these activities until the rapid growth in commercial air transportation led to a mid-air collision over the Grand Canyon on June 10, 1956 where all occupants of both aircraft were killed. This accident focussed attention on the fact that civil air transport activities were outgrowing the government organization and management capabilities for assuring public safety from hazards. During 1957 many investigations in and out of government were held regarding the general problem of air transportation, safety and design, manufacture, maintenance and operation. The culmination of all of these activities was the enactment of the Federal Aviation Act of 1958 which was signed into law by President Eisenhower on August 23, 1958, and which established the independent Federal Aviation Agency (FAA). The FAA assumed all responsibilities of the CAA which related to "promoting civil aviation" and regulating all aspects to assure safety to the public user.* The legislation also continued the existence of the CAB which became responsible for all non-safety related air transport activities such as route and schedule control, fares to maintain viable economics in the system, matters pertaining to amalgamation of carriers, subsidies to maintain needed public service, and service agreements with foreign carriers. The CAB also retained a responsibility for investigating accidents and making recommendations to the FAA with regard to inhibiting repetition of these events.

*An important increase in focus was toward positive in-flight control by FAA/ATC of all Civil Air Transports during cruise between take-off and landing.

Close examination of the organization and management of FAA to promote safety will be made subsequently.

To complete this background review it is necessary to note the formation of the Department of Transportation in 1967 into which the FAA was incorporated as one administration. A major force behind this action was the realization that various transportation modes had become highly interactive and the inter-modal problem had to be addressed in its entirely. Some credit should also be given to recognition that the FAA, in the face of major technical developments, had been able to ensure maintenance of a very high safety standard and that other transport modes would benefit from closer association with this activity.

One other action is of special concern here. With the formation of the DOT the transport accident investigation responsibility of the federal government was made a wholly independent activity unassociated with any other responsibilities. The National Transportation Safety Board assumed the responsibility from the CAB and thereby became an independent investigator with responsibility for all types of transportation accidents, reporting directly to the executive office of the President. Although this has created some conflict with other groups in separation of responsibilities,[9] it has done much to allay suspicion that promotion and regulation can lead to actions benefitting the industry more than the public. The system of checks and balances that has developed gives evidence that this separation of responsibilites was a wise action.

The direct role of the federal government has increased enormously in the course of maintaining public safety in air transport and achieving the remarkable safety record. For ex ample, in 1927 the DOC assigned 234 people to this effort. W en the CAA came into being in 1938 the employment was up to 2938 reached 4841 by 1940, and employment reached 25,805 by 1958 wh n the Federal Aviation Agency was formed. The current employme of the FAA is around 60,000. The cost of public safety is no low.

As will be discussed in a subsequent section, many elem nts in and out of government have been and are involved in hazard mitigation and research required to maintain safety in air tr ns- portation. The central core of this activity, however, has a - ways been found in the federal group assigned directly to hav responsibility for this task. For this reason the next step of this study will examine the current organization and manag - ment for hazard mitigation and research in air transport by t e FAA. (See Figure 2 for outline of current organization).

ORGANIZATION AND MANAGEMENT OF THE FAA

The FAA must organize for and manage a wide variety of cti- vities in meeting its responsibilities of maintaining a high tandard of public safety in the civil air transport system. These ac i- vities are contained for the most part within two major group ngs discussed in the following. These two groupings differ funda entally in nature in that in one case the FAA carries an operational s well as a regulatory responsibility, and in the other it carries o ly a regulatory (for safety) responsibility. It is this latter hich has most potential for broader application and which will be he focus of attention in this analysis.

One major responsibility of FAA is the development and operation of the federal airways system open to use by all qualified (equipped) aircraft.* With the cooperation of the industry, FAA makes decisions regarding technical changes and underwrites development, construction and operation of nearly all of the system. This includes terminal area operation aids and landing aids at all public airports. Weather services and all navigation aids and traffic control elements are part of the system. It is evident in this instance that FAA is responsible to itself for maintaining the safety of others through its own actions. A potential for conflict of interest which surfaces not infrequently, is also evident and is not yet generally resolved. Be this as it may, this responsibility is more or less unique and least likely to have broader application to hazard mitigation. For this reason it will not be discussed further.

The other major responsibility is the certification of all equipment, personnel and operations as to their safety for use in providing reliable air transport to the public by private operators. This responsibility is focussed under the Associate Administration for Aviation Standards and it is supported by the Associate Administration for Engineering and Development. (See Figure 3). There are many different challenges to meeting this responsibility which have been met with considerable success through a constant evolution of the system to its current form (see Figure 3). Some key examples of these challenges are as follows.

(1) With the large number of private and corporate

*This activity involves the large majority of the total resources, personnel and funding, available to the FAA and it is under the Associate Administration for Air Traffic and Airway Facilities. See Figure 2.

individuals involved in design, construction and operation of all elements of the system, it is impossible for FAA to supervise directly all activities. Thus a system of reassigning responsibility to the industry has been successfully evolved which enables a relatively few FAA employees to meet the responsibility.

(2) Much of the innovative development in the system (aside from the airways system) stems from industry initiatives which often cannot be anticipated by FAA. The certification and regulation of the system, then, must be handled with great flexibility to enable easy application of new technology without sacrifice of safety. Again with the cooperation of industry, this process has evolved so that such great technical changes as the introduction of the swept wing jet transport could be made with no pronounced change in levels of safety. This matter is constantly of concern as witness the current attention being given the new commuter aircraft operations resulting from de-regulation by the CAB of the trunk operations.[10]

(3) The operating elements of the system cover a wide range of (a) technical sophistication and (b) relations with the public which is to be protected. A uniform code and application would either impose undue hardship for some, or insufficiently protect the public in the case of others. To account for this the degree of regulation is determined by the degree of risk to the public. For example, a private flyer is regulated in the main by control over where he flies and in prohibiting carrying passengers for a fee.* In short, he primarily assumes risk for himself. On the other hand, the commercial designer, builder and operator who

*This is in the category identified as General Aviation.

plans to serve the public for a fee,* is supervised and regulated in every step of the activity. The federal government takes elaborate precautions to protect the public, whether it is using the system or just exposed to its operation.

This brings us to the consideration of specific actions which the FAA is responsible for in certifying the equipment, personnel and operation of the civil air transport system.

(1) Notification to FAA of a manufacturer's intent to embark on development of a new type commerical air transport or related flight equipment. At this point the preliminary design is reviewed by FAA to identify any features which may be in conflict with, or outside of existing and accepted design principles as set forth in the Code of Federal Regulations (CFR's).[11] Quite naturally, introduction of new and advanced technologies will cause such review to occur, and it becomes incumbent on the FAA to carry out any analysis required to accept or reflect changes in appropriate CFR's. In this endeavor help is often sought from other government activities such as the military or NASA.

(2) Detailed design development - As the design proceeds from preliminary to final stage, the FAA engineering staff follows each step to assure that sound practice is followed in accordance with applicable CFR's. This includes not only the strictly hardware aspects of the design, but also an examination of projected operational characteristics to assure no new hazards are being introduced. Such considerations as the "flyability" of the

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*This is in the category identified as Air Carriers.

vehicle (related to piloting work-load), redundancy or "back-up" to allow for safety in partial system failure, and human/ergonomic factors are reviewed in detail.

(3) Prototype development - As the manufacturer undertakes construction of the prototype model, FAA's manufacturing inspection groups supervise the various aspects of the proposed production line procedures. These will include overall quality control of materials, personnel qualifications, tooling, supervision, materials processing techniques, adherence to established assembly procedures, and control over subcontractors and suppliers. Again, as technology provides new materials (e.g., new alloys, synthetics) for which no appropriate CFR exists, FAA must examine and approve or reject these new proposals and arrive at appropriate modifications to the existing CFR's. During this period the basic flight and maintenance manuals for equipment operation are developed and reviewed by FAA to ascertain that all basic operations and systems are covered adequately, and that all potential emergencies are considered and proper actions clearly defined to counter hazards. Mockups and simulation of all systems are provided FAA to aid in examining all of the above.

(4) Production line development. The FAA inspection groups verify that conversion from the "hand-tooling" of prototypes to production techniques does not impair the quality control maintained for the prototype and that no procedures are incorporated which could permit subsequent deterioration of quality as production continues. These groups stay with the aircraft type so

long as production continues and are responsible for maintaining acceptable levels of safety as later design changes occur as a consequence of operational experience.

(5) Prototype Flight Test

In making pre-production sales, the manufacturer makes performance guarantees to the prospective purchaser. After initial flight test by the manufacturer to demonstrate the integrity of the vehicle, the FAA flight test group conducts an evaluation to assure the aircraft meets all flight criteria specified by CFR's throughout the complete operating performance envelope proposed by the manufacturer and, perhaps most important and difficult to determine, that a margin of safety exists so that inadvertant violation of the operating limits does not lead to more than a slight degradation of safety. Once again, the problems of creating new or adjusting old CFR's to accommodate new technology must be resolved. With this activity complete, the manufacturer is issued a type certificate and is free to market the vehicle. As mentioned earlier, the FAA maintains supervision over life-time type production to assure that no changes in design or processes arise which would degrade the safety level once established.

(6) Operational and Maintenance Regulation

Although the basic design, manufacturing and operation are identical for each of a given aircraft type, it is unavoidable that each user will need adjustments in these to meet his own system requirements. These may include variations on vehicle subsystems, variations in maintenance depending on route structure, (different weather conditions, different stage lengths, differing maintenance procedures and opportunities), and varying philosophies with regard to all aspects of training. It is the responsibility of the FAA staff to review and maintain surveillance over these many variations of the basic operational plan, to assure that safety standards are maintained and to assure that competence of all personnel is adequate and that understanding of any deviations from "standard" practice is clear and unambiguous. FAA must generally, then, approve a flight operation manual for each operation of a given type. As in the manufacturing process, this operational surveillance is maintained throughout the operational life of this type.

Selected Examples of Regulatory Problems

It is apparent from the foregoing brief outline of the FAA responsibility in maintaining public safety in air transport, that a very major and comprehensive organization and management system has evolved. Some specific examples of this evolution are discussed in the following.

(1) Organizational System for Regulation

Although initially the principle activities and responsibilities were centered in a single headquarters, these have steadily shifted to regional centers associated with the corresponding centers of air transport manufacturing activity. This has met the demands of making day-to-day surveillance of manufacturing, but has posed the questions of over-close association between regulators and regulatees and potential differences in interpretation of CFR's by various centers. To counter this, in part, various centers have recently been assigned lead responsibility for establishing, modifying and interpreting CFR's, for a given group of CFR's, which must be adhered to elsewhere (See Figure 3). For example, the Northwest Region has these responsibilities for all CFR's applicable to transport category aircraft.[12] In regulating design and construction of such aircraft under their cognizance, all other regions must adhere to the principles and interpretations established by the Northwest Region. Each center, however, retains final responsibility for approving all actions taken by manufacturers, or operators under its supervision. Headquarters retains final responsibility for major policy decisions which affect all elements of the air transport system safety - for example, the rate at which avionic control systems or composite materials are introduced into new aircraft.

(2) FAA Guidance with Changing Regulations

Quite naturally, in a rapidly changing and evolving system, any new or changed CFR must be made known to all affected. In the formative stages of Air Transport System regulations, advisory material was issued in a form that gave an interpretation of new or changed regulation and described in detail procedures to demonstrate that the regulation was met. It became apparent, with time, that this process was unduly stifling industry innovation in aircraft design and operation. As a consequence, early in the 1950's, issuance of advisory material relating to new or modified CFR's was discontinued and interpretation and demonstration of compliance left entirely to industry. This extreme proved unsatisfactory due to the great variation in interpretation and demonstration techniques prepared by various elements of the industry. More recently, issuance of advisory material has been resumed but in the form of defining a possible interpretation and a possible procedure(s) for demonstrating compliance. The government role remains advisory in nature leaving final interpretation and compliance demonstration together with responsibility for choice on industry. A wholly satisfactory solution to the division of responsibility between industry and government has not been realized.

(3) Staffing Problems of Regulation

Faced with an industry of the size and technical scope of the Air Transport System, it is clearly impractical for the federal government to provide supervision in the degree necessary to oversee all factors related to maintaining safety. To meet this responsibility the FAA Administrator is given authority to designate employees of the industry who are responsible to the Administrator as his representatives to assure that compliance with CFR's is maintained.[13] Despite the apparently conflicting position in which this places the employee, the system has proved remarkably successful. Any one major developmental program may have several hundred designated representatives associated with it; the specific employees are chosen by the employer. No doubt the great importance to the manufacturers and operators of avoiding hazards and disasters weighs heavily in the success achieved. It is clear to all that detection and avoidance of incipient problems are far more effective than attempting cures for built-in problems. While the success is not complete, the existence of the designated representatives has enabled FAA to assure a good safety record with a remarkably small staff.

(4) Question of "Minimum" Safety Standards

Operation of any vehicle without due attention to its state can lead to catastrophies. This is particularly true in the case of aircraft. To minimize this possibility, each aircraft design has a carefully developed "safe" operating envelope meeting "minimum" standards. This in turn is surrounded by a region where flight is possible, but with degraded safety. Much attention is given the problem of making the zone of degraded safety unmistakably evident to the operator so that inadvertent incursions into it can be corrected before catastrophe. Establishment of "minimum" safety standards is a complex and very subjective problem since competence and training of those involved in the operation are significant factors. This has been and will continue to be the center of much activity. The judgments made to date have been overly restrictive in the views of some, but they have been a major contributor to maintaining the safety record of the Air Transport System.

(5) Anticipatory vs. Reactive Regulations

From inception of the federal regulations activity a major question has existed as to whether the regulations should anticipate problems associated with new technology or react to them. It is argued in the first case that the government cannot anticipate new developments and any attempt to do so will just inhibit them. The counter argument insists that failure to anticipate will lead to increased hazard and catastrophe with new technologies. Examples can be found to support both contentions. For example, jet engine noise was not regulated until the existence of a public hazard was accepted. On the other hand, anticipatory regulations against powered controls to assist a pilot precluded their full use in the development of large commercial aircraft until extensive use by the military proved them acceptable. A system has now developed where so-called "tentative standards" are established as new technology appears on the horizon. These are made the subject of intensive discussion between industry, FAA and other appropriate federal agencies until a compromise is reached. Introduction of the new technology is approached with extreme caution and in a way that its failure would, at the most, involve curtailed operation and minor increase in hazard while avoiding catastrophe. An example is the gradual introduction of composite materials into structures where it is first used in non-primary elements or where redundancy can exist such as is found in multiple unit control surfaces. Thus, some degree of technological innovation can be achieved at the expense of only minor degradation of public safety.

ROLE OF OTHER GOVERNMENT AGENCIES, INDUSTRY AND UNIVERSITIES

Although the primary responsibility for hazard mitigation and research for air transport safety has been carried by a series of Federal Civil Aviation authorities, several other federal organizations as well as industry and universities have contributed significantly to this process. (See Figure 4).

The military services have assigned personnel to the civil authorities to develop and conduct technically-based research programs on safety and analyze the results of this work to lay the foundation for the specifications of safety standards. This has enabled an important cross-flow of safety considerations related to new technical developments since military programs often lay the foundation for later advances in civil air transportation.

The NACA/NASA* federally supported research activities have also made important contributions to the knowledge necessary to establish safety standards. Through its own research, NACA/NASA has been able to assist the civil regulatory group to be abreast of future technical developments and to conduct research programs directed specifically at hazard mitigation which these new technologies demand. An especially valuable contribution has been the close association between NACA/NASA and industry which is not generally possible between industry and regulatory authorities. This association has served often to ease the regulatory problems associated with introduction of new technology. NACA/NASA have long served as an advisory group to the authorities involved in accident investigation, assisting in the task of identifying accident causes and the steps required for mitigation.

Although the various civil air transport authorities have carried the responsibility of mitigating weather related hazards,

*NASA, the National Aeronautics and Space Administration, was created by Act of Congress and signed into law by President Eisenhower in 1958. NACA and its research responsibilities were incorporated into NASA by this Act.

several other federal groups have provided assistance in this task. In its various forms, the Weather Bureau* has provided current information on hazardous conditions for dissemination to operators by the civil aviation authorities. Several major research programs have been carried out jointly by federal agencies to examine specific weather related hazards. Examples include the studies of severe storms* (thunder storms, tornadoes, cyclones) and clear air turbulence, studies of fog characteristics and techniques for dispersal, effects of lightning strikes on aircraft structures and electrical systems, and analysis of wind shears encountered during landing. All of these joint activities have laid the groundwork for information dissemination by the civil air transport authorities directed at mitigation of weather related hazards.

In addition to the federal organization and management system for hazard mitigation in civil air transportation, the private industrial sector also plays an important role. Thus the airframe, engine and electronic industries provide essential hardware for the air carriers and the air traffic control system. The airline industries employ this hardware in furnishing air transportation to the public. These industries form, together with The Federal Aviation Administration, a closely coupled system for hazard mitigation and control.

In the development of hardware, the airframe, engine and electronic industries operate under a wide variety of aviation standards which govern the design of aircraft, engines, avionics

*The Weather Bureau is now located under the National Oceanic and Atmospheric Agency which has also contributed to severe storm studies.

and air traffic control hardware. These standards are promulgated and enforced by the Federal Aviation Administration as noted earlier. Thus airframes and engines, for example, cannot be employed in the civil air transportation system unless they satisfy these standards and receive airworthiness certificates issued by the Federal Aviation Administration. Industry management and engineering personnel are very familiar with these standards and in a new design they work closely with personnel of the regional staffs of the Federal Aviation Administration.

As noted previously, because of the enormous task of ensuring that a new design satisfies the aviation standards, the Federal Aviation Administration delegates much of its authority to Designated Engineering Representatives (D.E.R.'s) who are employees of the manufacturing company. It is quite apparent that the airworthiness of new aircraft, engines and other hardware is highly dependent on the quality of the design and manufacturing activities of the industry. This requires an industry which is dedicated to high quality engineering and production, and which has a considerable investment in laboratory and other development equipment such as wind tunnels,strength testing devices and computers. It is important too that the industry has a significant amount of long-term stability and corporate memory. The success of modern civil air transports is dependent very largely on the ability of U. S. industry to build into new designs the lessons learned from the performance of past designs. Each industry has developed its own design manuals which reflect this past experience. Because of the sensitivity of new designs to FAA's aviation standards, changes in these standards are made only after extensive consultation with the manufacturers, as will be considered in detail subsequently.

The airline industry operates also under stringent aviation standards prescribed and enforced by the FAA for maintenance and inspection. Maintenance procedures and inspection periods are agreed to collectively by the manufacturer, the air carrier and the FAA. Again, because of shortness of personnel and the enormity of the task, the FAA deputizes air carrier personnel to enforce the standards and provide stamps of approval. These personnel are industry employees who have passed FAA examinations for the Aircraft and Power Plant (A and P) licenses. It is again apparent, that much of the responsibility rests on the integrity of the air carrier, the quality of its maintenance and inspection functions, and its commitment to safety. The major trunk airlines have particularly high quality staffs of engineers and mechanics, elaborately equipped maintenance and overhaul depots, and procedures which have evolved from years of experience. The FAA places great reliance on the integrity of these organizations.

Three of the principal lessons learned by industry throughout the history of the civil air transport system are as follows:

(1) Basic safety and quality cannot be <u>inspected</u> into an engineering system. They must be built in originally by the workers (design, manufacturing, et al).

(2) Continuing safety and quality depends on having uniformly high technical standards across the board in design, construction, maintenance and inspection.

(3) Industry, both manufacturing and air carrier, must have a significant amount of stability so that it can acquire competent people, laboratory and depot equipment and a corporate memory which allows it to build on experience. An economically sick industry may tend to provide unsafe air transportation in spite of the FAA's attempts to enforce safety. This was one of the factors which prompted the regulation of our airline industry in the beginning and which is being given new attention in connection with the recent deregulation*move. (See Ref. 10)

In addition to interacting closely with the FAA in maintaining high safety standards in current operations, the industry's unique competence is used by FAA under special contracts. These may examine safety implications of new technical developments or re-examine known hazards which give evidence of assuming increased importance as operational patterns change.

Examples of the first type are the studies made to provide the basis for development of airworthiness criteria for powered-lift aircraft (Ref. 14). Such aircraft are designed to enable installed power to create lift as well as thrust in order to

*This is phased deregulation of the CAB's functions in determining routes and fares for air carriers.

reduce take-off and landing speeds and distances. Successful achievement of the capability is of prime interest since it counters the growing need for ever-longer airport runways. Such a new capability would require an additional set of safety regulations applicable to operations in this mode.

An example of the second type of FAA/industry contract work is the ongoing industry study of the disturbed atmosphere (wake) left behind a landing aircraft. As aircraft have become more disparate in size, smaller aircraft have experienced severe upsets when following large aircraft too closely during a landing. To assure safety in operation, FAA has been forced to increase separation distance, consequently reducing the number of operations in any time period and restricting use of already crowded airports. Industry is providing FAA with information to establish safe spacing while also seeking other means to mitigate the hazard.

The participating industry, designers, manufacturers and operators of all elements of the system also play a major role in developing regulations directed at hazard mitigation. The procedure followed (Ref 15), developed over many years of refinement, is that of announcement by FAA to industry of a proposed hazard-mitigation change or amendment in regulation (NPRM)* evolving from the FAA or from the studies of the groups cited in the foregoing comments. This is followed by a series of meetings between industry and government during which the proposal is

*Notice of Proposed Rule Making (NPRM)

analyzed in detail and an acceptable definition of the new regulation is reached. A particularly important part of this activity is the close and detailed examination of the operational and economic impacts of any change which can be accomplished only with full and open participation of the industry. This is especially necessary in making a determination of the phasing in of any new safety related regulation in order not to disrupt the civil air system, either operationally or economically. The subject of these meetings may be very broad, such as the spacing required between following aircraft during landing approach to avoid wake turbulence upset accidents, or use of simulation as a substitute for flight training. The subject may also be relatively narrow and specific such as approval of a new instrument type.

Throughout all of these various activities, expert advice has been sought and obtained from the research and analysis capabilities in many universities with strong aeronautical and transportation science programs. Representatives from these university programs advise on nearly every program for federal aeronautical research, and they serve on the advisory groups aiding the conversion of this research into the basis for improved regulations to mitigate air transport hazards. The role of universities has been more profound and pervasive than this, however, in the development of civil air transportation, and it therefore deserves further attention. This role has been rooted primarily in the education of aeronautical engineers, although aeronautical research of importance has also been conducted at universities. In the beginning, aeronautical engineers were educated as mechanical engineers, naval architects or were self taught. Aircraft design was crude and often not based on rational scientific principles. It was this realization that led to the formation of the National Advisory Committee for Aeronautics (NACA) in 1915. But, it was a private foundation, and not the federal government, which provided the needed impetus for aeronautical engineering education in the United States. This was the Daniel Guggenheim Fund For the Promotion of Aeronautics created in 1926. It was Daniel's son, Harry, that led Daniel Guggenheim into aeronautics. Harry had become impressed by the possibilities of aviation as a naval pilot in World War I. When he returned to the United States after the war he was appalled to find American aviation far behind that of Europe, languishing for lack of enthusiasm and money. The government seemed to be largely ignorant of the potential of civil aviation, and a surprisingly conservative American public balked at the idea of civil air transport. The first significant move by the Guggenheim Foundation*was that of creating a school of aeronautics at New York University with a $500,000.00 gift on June 16, 1926. This was followed by such steps as supporting tours by Richard E. Byrd and Charles Lindbergh, the setting up of the Full Flight Laboratory For the Study of Fog Flying, the perfection and manufacture of the first gyroscopic compass for aircraft, a $100,000.00 prize for the manufacture of the safest aircraft, a model weather reporting service, and the first American commercial airline - Western Air Express -

*This was the first of a number of associations and foundations formed in support of civil aviation, including the Flight Safety Foundation.

operating between Los Angeles and San Francisco. But the large impetus to aeronautical engineering education came in 1929 with the establishment of schools of aeronautical engineering at MIT, Georgia Tech, California Institute of Technology, University of Washington, Stanford, and the University of Michigan. These schools were rapidly copied at many other universities and the aeronautical industry was, by 1940, at the time of the outbreak of World War II, assured of a plentiful supply of scientifically grounded aeronautical engineers. It was this event and this group of trained people that contributed more than any other single factor to subsequent U. S. leadership in providing a safe and reliable air transport system.

Aeronautical engineering education, as it evolved in the United States, was unique in the field of eigineering education. To begin with, it was necessarily solidly grounded in science. The student received a thorough understanding of aerodynamics, structures, propulsion, stability, guidance and control. But what was unique in the first rate schools, was that the student was also taught how to combine these building blocks into a flight vehicle and operating system. There was developed a strong orientation toward the vehicle and the system with an emphasis on combining performance with safety. The attitudes and viewpoints taken by these students into the federal government, and into the aeronautical manufacturing and air carrier industry contributed enormously to its successful evolution and its acceptance by the public as a safe and reliable transport mode.

SELECTED ISSUES, PRINCIPLES AND POTENTIAL APPLICATIONS

It is clear from the previous considerations of the various government agencies, industries and universities in the regulation for safety of the civil air transport system that, in the large, the role of the FAA has moved away from more centralized authority, which tended to characterize its earlier predecessor agencies, toward de-centralization and a role for FAA which might be characterized as a "first among equals" within the government-industry-university team in the civil air transport system of today. The intricate and effective working of this system is critical not only to the safety of the millions of individuals involved in and using the system, but also to the economic well being of the nation. A few salient facts point this up:

-- U. S. aviation industry employs about one million Americans

-- U. S. aviation industry is the second largest among U. S. manufacturing employers.

-- Aeronautical products contribute more than any other manufacturing industry to the U. S. balance of trade. In 1979 U. S. aeronautical exports amounted to nearly 12 billion dollars, second only to food stuffs.

-- American airplanes comprise 85 per cent of the free world's commercial jet aircraft.

The safety record for commercial aviation is good.[16] The following chart shows statistics of the National Transportation Safety Board (NTSB) on annual transportation fatalities from 1973 to 1978.

Transportation Fatalities

	1973	1974	1975	1976	1977	1978 (note a)
Highway	54,615	44,950	44,690	45,523	47,876	50,145
Grade crossings	1,185	1,250	910	1,174	1,001	1,064
Railroad (note b)	777	582	564	590	644	632
Marine	2,074	1,854	1,860	1,533	1,528	1,500
Aviation						
General	1,412	1,290	1,324	1,341	1,395	1,548
Air carrier	227	467	124	45	654	161
Pipeline	70	34	30	82	43	33
Total	50,360	50,427	49,502	50,288	53,141	55,083

a/ Based on preliminary statistics released on May 12, 1979.

b/ *Figures include rapid rail transit.*

This table is indicative only, since numbers of miles traveled, number of passengers and related matters vary markedly from one mode of transportation to another.

The size and economic well being of the aviation industry, and a good safety record are not benefits without public costs, however. Two indicators of this show the Federal Aviation Administration:

-- Had over 55,000 full-time employees on September 30, 1979, and

-- Spent about 3 billion dollars for fiscal year 1979.

It is pertinent, therefore, to examine some overall trends in public costs and associated effectiveness of safety regulation by the FAA over the evolution of its organization and management system.

Some Considerations of Public Costs and Associated Effectiveness

Table A presents historical information on total personnel and budget appropriations (measured in 1972 dollars) for the FAA and its predecessors between 1927 and 1978, emphasizing the 1970's. Over the past 30 years, the largest increases over a 5-year period occurred between 1955 and 1960, when personnel increased by almost 23,000, almost 150%, and the budget by $619 M or nearly 300%. This corresponds to the time period in which the FAA was established with substantially enlarged operating activities. *

Now it is useful to examine accident rates occurring under the most rigorous set of regulations (e.g., certified air carriers) and under a less rigorous set of regulations (e.g. general aviation). Table B presents the accident rates of U. S. Air Carriers between 1950 and 1978. Air Carrier operations included certified route carriers, supplemental carriers and commercial operators of large aircraft. It is seen that the absolute number of accidents in 1978 is one-quarter of what it was less than three decades earlier, while the number of aircraft miles flown has increased five-fold; thus, there has been a dramatic fall in the accident rate per million plane miles. Table C contains the accident rate of U. S. General Aviation during the same period. General Aviation refers to the operation of U. S. Civil Aircraft owned and operated by persons, corporations, etc., exclusive of

*These figures are the aggregate of the FAA budget; in recent years that portion of the budget concerned solely with development and enforcement of safety regulations is roughly two orders of magnitude less.

Air Carriers. Again, the accident rate has declined substantially with time. The number of accidents has remained fairly constant over the decades, while the number of aircraft-miles flown has quintupled. While differences exist in the nature and quantity of the operations of Air Carriers and General Aviation, it can still be inferred that the more extensive hazard mitigation regulations applied to the former have significantly contributed to its much more impressive safety record. (Some two orders of magnitude better by 1978 - see Tables B & C).

This inference is supported further by another view of the impact of different generic levels of safety regulation applying to Air Carrier operations: that governing scheduled commercial service and that for unscheduled service, such as commuter and charter operations. In 1972 the NTSB published the "Air Taxi Safety Study" which analyzed past statistics and concluded "The less stringent regulatory requirements placed upon the air taxi/commuter industry result in a level of safety lower than that of the certified air carrier industry."[17]

It would be interesting and informative to use this comparative accident rate information to analyze in detail the costs and benefits of hazard mitigation regulations and control. Unfortunately, there is no directly accessible information on the differing costs of the various regulatory levels. It is true, however, that safety regulation and control of U. S. air carriers are the dominant driving forces and large majority of the budget of FAA. We are able, therefore, to make an approximate macro-level comparison of the cost-effectiveness of air safety regulation of these carriers by comparing the budget of the FAA with the accident rate per million plane miles they traveled. This is done in Figure 5 which is drawn from the data presented in Tables A and B.

It is clear from Figure 5 that over the period from 1950 to 1978, a 5-fold increase in the FAA/CAA budget was attended by almost a 20-fold decrease in accident rate of U. S. air carriers. The first decade of this period was characterized by improved aircraft design, development, operations and maintenance by industry in accordance with strengthened FAA/CAA safety regulations, and by expanded FAA operational activities especially in the areas of air traffic control. The second decade sustained these trends with corresponding decreases in accident rates. These accomplishments were achieved with strengthened organization and management of FAA as discussed earlier in this report, and in the face of continued major increase in air travel and the transition from propeller to jet aircraft by the carriers. The third decade from 1970 on has been characterized by the introduction of 2nd generation jet aircraft, including the jumbo jets, into the air transport system and the maturing* of the safety regulation of this aircraft operating environment.

Another insight into the effectiveness of air safety regulation in mitigating hazards is afforded by a comparison of the air transport fatality rate with that of other transportation modes. Each of the other transport systems are regulated for

*It is noteworthy and inevitable that this maturing process has revealed additional opportunities and needs for improvements in the organization and management of the FAA to deal with safety hazards, and these matters are discussed briefly in Appendix B.

safety to some degree, but none approach the extensive regulation by the federal government of the civil air transport system. Table E presents the comparative safety rate of intercity transport modes in the U. S. between 1940 and 1976. In 1940 the fatality rate for air travel is one of the highest of all modes. By 1975 - 76 the fatality rate for air travel is among the lowest of all modes, while travel by air constituted more than 80% of all intercity travel. Throughout the years, all systems of transportation have exhibited a reduction in fatality rates. Even so, the air transport system's relative reduction far outstrips gains made by other modes; the ratio of 1976 air fatalities to 1940 air fatalities is .001.

Through the decades, the American public has become increasingly mobile. Table E shows that travel by air, rail and bus has increased more than three-fold in the past three decades. The civil air transport system has gained an increasing share of an increasing market. Its safety record now compares favorably with those of bus and rail which are the more regulated of the ground carriers. These facts attest to the effectiveness of the hazard mitigation regulations governing the civil air transport system. They reveal clearly why public confidence has been established in a basically hazardous operation with the result that it produces billions of dollars a year in revenues, it meets a basic transportation need for millions of passengers and it provides about a million jobs for Americans. This is a unique government-industry-university accomplishment, and the hazard mitigation techniques underlying this success merit serious attention wherever and whenever achieving national goals may involve major technological efforts which contain the elements of major hazards requiring mitigation.

Some Principles and Potential Applications

As noted at the outset of this report, two principles have undergirded the early and continued leadership of safety regulation by the Federal Government in the enterprise of air commerce:

1. It was recognized from the beginning as an inherently and substantially hazardous enterprise to the exposed public[3] - one, therefore, that could not be left up to various parts of the developing industry or to various state and local government authorities to independently regulate for effective safety. Thus, it was an enterprise which required basic uniformity in organizational and management of operations to ensure and maintain safe procedures, including the effective management of any emergencies that might inadvertently develop.

2. It was recognized early that commercial aviation, if it was to grow and prosper, had to be considered as an interacting set of subsystems in which no critical subsystem could be ignored or otherwise neglected if the inherently dangerous aspects of the enterprise were to be anticipated and controlled. Thus, effective coupling and communication within and between elements of the system was essential, along with rigorous and timely incident and accident investigation and reporting.

It is no surprise in the light of these observations that the later development and industrialization of nuclear power was also regulated from the outset by the federal government. What is surprising, in the light of the Three Mile Island nuclear power plant accident, is that fundamental lessons learned in hazard mitigation in earlier civil air transport system experience may not have been fully followed in the implementation of nuclear power plant systems. These lessons appear to include the need for regular, realistic and standardized training in emergency management procedures, for dedicated and precise emergency communication within and across organizational boundaries, and for rigorous incident as well as accident investigation and reporting.[18, 19, 20] These matters and others in the area of hazard mitigation are now being pursued by the Nuclear Regulatory Commission (NRC)[20] and the success of this improved safety regulation effort may well determine the degree to which nuclear power becomes a major alternative energy resource in the United States.

Exploitation of synthetic fuel production and accelerating utility conversions are additional areas in which the nation is in the process of aggressively moving* to reduce its dependence on imported oil and achieve energy self sufficiency. Thus, the nation either already has established or is in the process of establiing specific national goals for major reductions in oil (and gas) consumption by the next decade, and it either already has established or is in the process of establishing aggressive federal "financial incentives" programs and institutions to aid

*These initiatives are embodied directly in the Energy Security Act of 1980 in the case of synfuels, and they derive directly from the Fuels Use Act in the case of utility conversions.

in meeting these goals. It is clear too that domestic coal will be among the most prominent if not the dominant alternative fuel utilized in these initiatives (i.e., 2 MBD equivalent by the next decade) and it is important therefore to perceive the implications of this utilization. In the aggregate[21] it will require almost doubling the amount of coal mined in the U. S. (i.e., from 0.7 billion short tons per year now, to 1.3 billion by the next decade), and the amount of coal transported to meet regional needs like in New England may be required to increase by an order of magnitude (i.e., from 1 million short tons per year now to 10 million by the next decade).[22] From another perspective,[23] these initiatives will require the creation of some 25 major new synthetic fuel production plants at a cost of several billion dollars each, and the conversion of well over 100 utility plants at a cost ranging from tens of millions to a significant fraction of a billion dollars each over the next decade.[22] The corresponding manpower requirements will be in the tens of thousands for engineers and the hundreds of thousands for skilled workers, and there will be major challenges in the planning, managing and financing of the rapid growth of population centers in new industrial development areas.[21] These developments will not be free of the requirements for careful attention to hazard mitigation, since, for example, each major synthetic fuel production plant is in fact a large processing plant for highly energetic chemicals with the ever present danger of inadvertent releases of unsafe quantities of toxic substances, or of fires or explosions.* These hazards are also present in the mining, storage and transportation as well as the production processes, consumption and waste disposal. Therefore, hazard mitigation will require careful attention from the outset in the development of the overall synfuels system.

From the larger point of view there is a potential major barrier to achieving the national goals for synfuels production and utility conversions by the next decade. This major barrier is embodied in the cumulative lost time and the increased expenses that can be incurred by not identifying in advance the individual and collective barriers to success that may be encountered in the undertaking, and/or by not preparing for the effective alleviation, avoidance or elimination of these barriers. These barriers may be scientific or technical, development or operational, legal or regulatory, or management or budget in nature, or combinations thereof. Their likelihood of onset with attendant adverse effects on achieving the national goals will be markedly enhanced by the number, diversity, complexity and interactions of the new energy systems to be "concurrently"brought on line, and the existing systems to be "concurrently" converted or upgraded over the next decade.** Inadequate attention to hazard mitigation can exacerbate any one or all of these barriers to the national detriment as well as to the detriment of the portion of the public immediately exposed to an accident.

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*This reminds us of the hazard of a Texas City type disaster which is in no sense paled by the Three Mile Island type nuclear power plant accident discussed earlier.

**It is noteworthy in this connection that a major new synfuel production plant or a major utility conversion is likely to require the better part of a decade from inception to completion, and the permitting process alone could extend this time significantly.

It is for these reasons that a comprehensive analysis of potential hazards and how best to mitigate them appears urgently needed for these emerging new energy systems. Such an examination should certainly include a careful view to the applicability of the lessons of hazard mitigation learned in commercial aviation which are pertinent thereto. It is noteworthy that in this case, however, no federal agency other than FEMA appears to have the overall national oversight authority for hazard mitigation involving the operation of all elements which make up the coal energy systems ranging from mining (under DOI) to conversion (under DOE) and transportation (under DOT) and waste disposal (under EPA) to name but a few. Many responsibilities for these systems reside, too, under state and local government authorities, and of course industry as the prime mover, but all of this serves only to emphasize the need for early and comprehensive visibility on effective, widely applicable hazard mitigation principles and practices for these systems from design through development, operation, and inspection and maintenance. Thus the analysis noted earlier, including consideration of applicable hazard mitigation experience in civil aviation, certainly appears timely and it may well be a logical FEMA leadership responsibility. Indeed, it could provide a long step towards not only identifying but achieving agreement on what hazard mitigation principles and practices should be implemented, and who should implement them and how. In short, it could provide not only the substance but the vehicle for the intranational government - industry

-university team to start getting its hazard mitigation act together in advance of and hopefully to the exclusion of the onset of major safety problems and the portent of catastrophic accidents in the developing new and enlarged coal energy systems of the future. In such an undertaking, FEMA's role could be likened to the partnership aspect of FAA of today-that is working as a first among equals with industry and other government agency partners,and with the support of universities, to mitigate hazards and achieve levels of safety in the major transition to alternative energy resources that will maintain public confidence in,and support of achieving the national goals.

Some principles of effective hazard mitigation in civil aviation that may well meet important needs in the role of government in this undertaking are as follows:

1. The need for organization and management arrangements to be flexible and adaptable in keeping with the changing nature of technology and its application to new commercial systems without sacrifice of safety and in full cooperation with industry.*
2. The need to aggregate under common direction those safety functions which are inherently closely related like the certification, security and operational standards of new equipment and systems.
3. The need to organizationally separate important functions with real or perceived conflicts of interest.

*It is noteworthy in this connection that to the extent that it is appropriate for government to support R&D on new systems, this function can be supported in greater harmony and cooperation with industry to enable effective commercialization when it is organizationally separate from regulatory functions.

This certainly includes the separation of safety regulation from economic regulation (to whatever degree it exists), and the separation of accident and incident investigation from both of these functions and placed at an appropriate level of independent organizational status.

The development and implementation on a large scale of alternative energy systems surfaces a portion of another emerging national problem, namely the safe handling of increasing quantities of hazardous materials. These materials include[24] poisons, oxidizers, combustibles, explosives, corrosives, radioactives, flammables, and toxic liquids or gases. As noted by FEMA[2], "Incidents involving the release of hazardous substances present serious health and environmental concerns". At the same time it is noted that "The dimension of the hazardous materials problem facing the country are not fully understood -- although the exact number of spills is unknown, Environmental Protection Agency estimates project an average of 2,216 spills in excess of 100 gallons (hazardous non-oil chemicals) each year through 1982. On another scale, Tennessee reported over 2,000 spills requiring state intervention in 1978. Major plant explosions are another dimension of spills." Both the product and process stages of handling hazardous materials have a number of phases ranging from raw material to waste, and fromextraction to disposal. It is far beyond the scope of this report to carefully examine the hazard mitigation problem in any one of these phases, but consideration of one phase, namely transportation, will serve to indicate the nature of the problem.

Tables E and F are taken from Reference 24 and they show the reported number of hazardous materials incidents and accidents during transportation, and the reported property damage (Dollars) associated therewith over the time period from 1971 to 1978. It appears from Table E that apart from "Freight Forwarders" and "Other", the annual number of incidents and accidents in all transportation modes including air is going up over this time period. According to Table F the corresponding property damage fluctuates with time over this period, although as noted the actual damage/losses can be as much as an order of magnitude higher than that "Reported". Thus, while the size of the transportation problem may well be growing, its actual magnitude appears to be substantially unknown. It is clear, therefore, that the first requirement to be met in working to improve safety in the transportation of hazardous materials is the establishment of rigorous and timely incident and accident investigation and reporting procedures. Accurate data will then be obtained to provide a basis for improved hazard mitigation. This paucity-of-accurate-data problem characterizes much of the broader challenge of improving safety in the handling of hazardous materials.

APPENDIX A

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APPENDIX B

SOME OPPORTUNITIES TO FURTHER IMPROVE AIRCRAFT SAFETY AND AVOID CONFLICTS OF INTEREST

It is pertinent to further examine in summary manner some issues relating to mitigation of hazards in commercial aviation which can be considered unresolved or only partially resolved.* Knowledge of such issues can also be useful in any effort to use hazard mitigation experience in civil air transport as a benchmark in other hazard mitigation efforts. One such issue was recently raised by the General Accounting Office (GAO) in its report[25] entitled How To Improve The Federal Aviation Administration's Ability To Deal With Safety Hazards. GAO contends that FAA has not done an effective and timely job of developing systems to identify safety hazards. GAO further contends that FAA has not recognized "the importance of hazard identification systems." The GAO report goes on to point out that this has, in GAO's view, stemmed from lack of attention to appropriate information gathering**

**In Reference 3 a related activity initiated in 1975 by FAA was discussed. Not resolved, although referred to in Reference 3, are legal questions associated with assignment of liability, invasion of privacy, etc. which may arise from enhanced information gathering activities. As hazard mitigation activities are expanded, these aspects of necessary information gathering will require specific attention.

*It is stated in reference 1 in the case of FAA, and in reference 3 with regard to the entire civil air transport system that there is a continuing need to upgrade the technical proficiency of personnel across the spectrum of function from design through development, operation, maintenance and inspection including certification of all key elements of the system.

and analysis and no single organizational focus for hazard identification.

> "FAA's main mission is to promote aviation safety. Since the first step in eliminating safety hazards is to recognize them, FAA collects and analyzes an abundance of information on aviation. However, although FAA's hazard identification efforts have been numerous and varied, they have been hindered by insufficient information gathering, limited analysis that has not fully employed state of the art capabilities, and an inadequately planned and coordinated agency approach. Further, FAA has not addressed known weaknesses in its hazard identification efforts in the most timely manner.
>
> "An August 1979 FAA report, confirming previous studies, found underused and ineffective accident and incident data systems."

On March 2, 1979 the Office of Aviation Safety initiated a new safety analysis project based on a 1978 study of safety analyses in rulemaking. This study, to cost between 2 and 5 million dollars, is being managed by DOT's Transportation Systems Center which has been doing similar work for the Federal Railroad Administration.

> "The project was originally planned, in part, to develop long-term methods and systems to better use data bases and analytical techniques to support regulatory activity. In late April 1979, FAA established a task force made up of representatives from all appropriate FAA organizations to develop an overall plan for aviation safety information systems. By June 1979, work had begun on increasing the scope of the long-term study. In order to accomplish the main goal of the effort - improving FAA's analytical capabilities -- FAA had to have better information. Consequently, the study's expanded tasks included determining FAA's real safety information requirements, critiquing existing systems and designing a comprehensive safety information system. This system would collect, process, and disseminate safety-related information for use in licensing, regulating, inspecting, monitoring, and controlling the civil

> aviation industry and the National Aviation System. In this way, according to the study's work description, the manufacture, operating, and maintenance of aircraft, as well as the rating and certification of airmen, could be sensibly managed. The description noted that the June 1979 DC-10 groundings and the growth of the air taxi/commuter and general aviation industry were strong forces to increase the role of existing safety information systems."[1]

The GAO report cited previously also states that FAA has not paid sufficient attention to collecting and analyzing human factors data in relationship to the agency's responsibility for air safety.

> "FAA's information about human factors includes data on pilot and controller error and the ability of humans to survive crashes. Although air safety has improved steadily since World War II, about 60 per cent of air carrier accidents and about 80 per cent of general aviation accidents still involve human error. To date, FAA has not collected enough information about human factors to address the underlying causes of human error and injury, although it is now striving to improve its data bases in this area."

It is becoming increasingly evident that improved understanding of human factors will be required to achieve hazard mitigation in a society ever-more dependent on advancing technology (including air transportaiton). With simpler technologies, human controllers can easily understand and sense the state of the various subsystems being managed. As technology sophistication increases, the human becomes only a link (and sometimes only a back-up link) between complex subsystems whose function and state are understood fully by only a few specialists. The problem is being addressed by each group associated with advancing technology but with these activities inter-related in a generally ad hoc manner. No clear means exists to resolve this growing problem. This weakness will require serious consideration in further efforts to mitigate hazards arising from modern technological activities.

An interagency problem that exists in civil aircraft safety is the perceived lack of a common data base as between FAA and the National Transportation Safety Board on accident and the incident information.[25] This problem can be expected when functions related to safety are assigned to a number of different agencies for the legitimate reasons cited in the main body of this report. This means that such critical interagency responsibilites as incident and accident information systems may require essential coodination and integration by a responsible independent agent of the President such as FEMA.

Two additional issues with interagency implications are related to the question of separating from FAA the following two currently assigned functions:

1. Promote air commerce and civil aviation at home and abroad.
2. Operation of the National Aviation System.

Over the years there has been a series of questions as to whether or not these two functions were not in conflict with FAA's other regulatory functions, particularly those related to aviation safety. To separate either one or both of these functions from FAA would either create new independent agencies*

*In the case of the National Aviation System the possibility has also been discussed of operating it under contract to the government.

or additional functions within existing agencies. This in turn would create additional requirements for interagency coordination and possibly recognition at the Presidential level for formal methods of interagency integration and coordination.

Another area of concern within the conflict of interest arena is the one generally referred to as organizational conflicts of interest. This is the situation where a private contractor proposes specifications or actions taken by the contracting agency which might impact, either directly or indirectly on the interests of the contractor. For a long period of time, such organizational conflicts of interest surfaced only when a situation developed in which there were so blatant a privileged relationship or an unfair competitive advantage to a contractor over other less happily situated that it rose to a level of a scandal.

As a result of such causes and the criticism to which they gave rise, some executive departments and agencies promulgated rules for the guidance of procurement officials in an attempt to reduce or curb such conflicts. One of the prime examples of such administrative efforts is found in section 1-113.2 and Appendix G of the Defense Acquisitions Regulations. The paramount purpose of this regulation was to prevent situations evolving in which a contractor might find itself performing for the contracting agency conflicting roles which might impact on the contractor's judgment and afford him an unfair competitive advantage over other private interests.

Since many executive agencies have failed to adopt regulatory guidelines governing organizational conflicts of interests, the issue has remained one of official concern. Congress has entered the arena by providing strictures against such conflicts as pertaining to the Department of Energy. In addition, Congress during its last session, considered a "Consultant Reform Act."

Nevertheless, it cannot be denied that organizational conflicts of interest continue to be a problem in the procurement of executive agencies in general, as highlighted by recent Congressional hearings, General Accounting Office studies, and investigative reports by the media. The Office of Federal Procurement Policy is attempting to respond to the continuing problem in the form of a draft Federal Acquisition Regulation ("FAR") on organizational conflicts of interests (subpart 9.5 of part 9, "Contractor Qualification"), which is currently circulating for comment. In the absence of a provision on this topic in the existing Federal Procurement Regulations, the primary model for the proposed FAR is, not surprisingly, section 1-113.2 of the DAR, as perceived in the light of contractors' experience with that provision.

It is clear that one lesson derived from such experience is the necessity to spell out clearly conditions which will be considered to give rise to an organizational conflict of interest, so that potential contractors know what restrictions they face prior to entering into contracts with government agencies, rather than having such prospective guidelines imposed upon them after work under contracts has begun. Moreover, since different organizational conflicts of interest issues are presented by contracts for consultant services as opposed to those for goods and services, it is important that any proposed regulatory reform in this area would distinguish between these two forms of procurement.

Responsibility / Year	Accident Investigation	Certification: Aircraft Airmen Operations Maintenance	Develop and Manage Airways	Proscribe Airport Safety of Operation	Regulate, Sponsor, Assist and Control Economics
1926	Dept of Commerce Aviation Branch	Dept of Commerce Aviation Branch	Dept of Commerce Aviation Branch		Dept of Commerce Aviation Branch
1928	Dept of Commerce Accident Investigation Board	Dept of Commerce Aviation Branch	Dept of Commerce Aviation Branch	Dept of Commerce Aviation Branch	Dept of Commerce Aviation Branch
1938	President Air Safety Board	President Civil Aeronautics Authority	President Civil Aeronautics Authority	President Civil Aeronautic Authority	President Civil Aeronautics Authority
1940	President Civil Aeronautics Board	Dept of Commerce Civil Aviation Administration	Dept of Commerce Civil Aviation Administration	Dept of Commerce Civil Aviation Administration	President Civil Aeronautics Board
1958	President Civil Aeronautics Board	President Federal Aviation Agency	President Federal Aviation Agency	President Federal Aviation Agency	President Civil Aeronautics Board
1967	President National Transportation Safety Board	Dept of Transport. Federal Aviation Administration	Dept of Transport. Federal Aviation Administration	Dept of Transport. Federal Aviation Administration	President Civil Aeronautics Board

Note: Responsible group reports to underlined office.

Fig. 1- Evolution of Federal Civil Air Transport Regulatory Authority

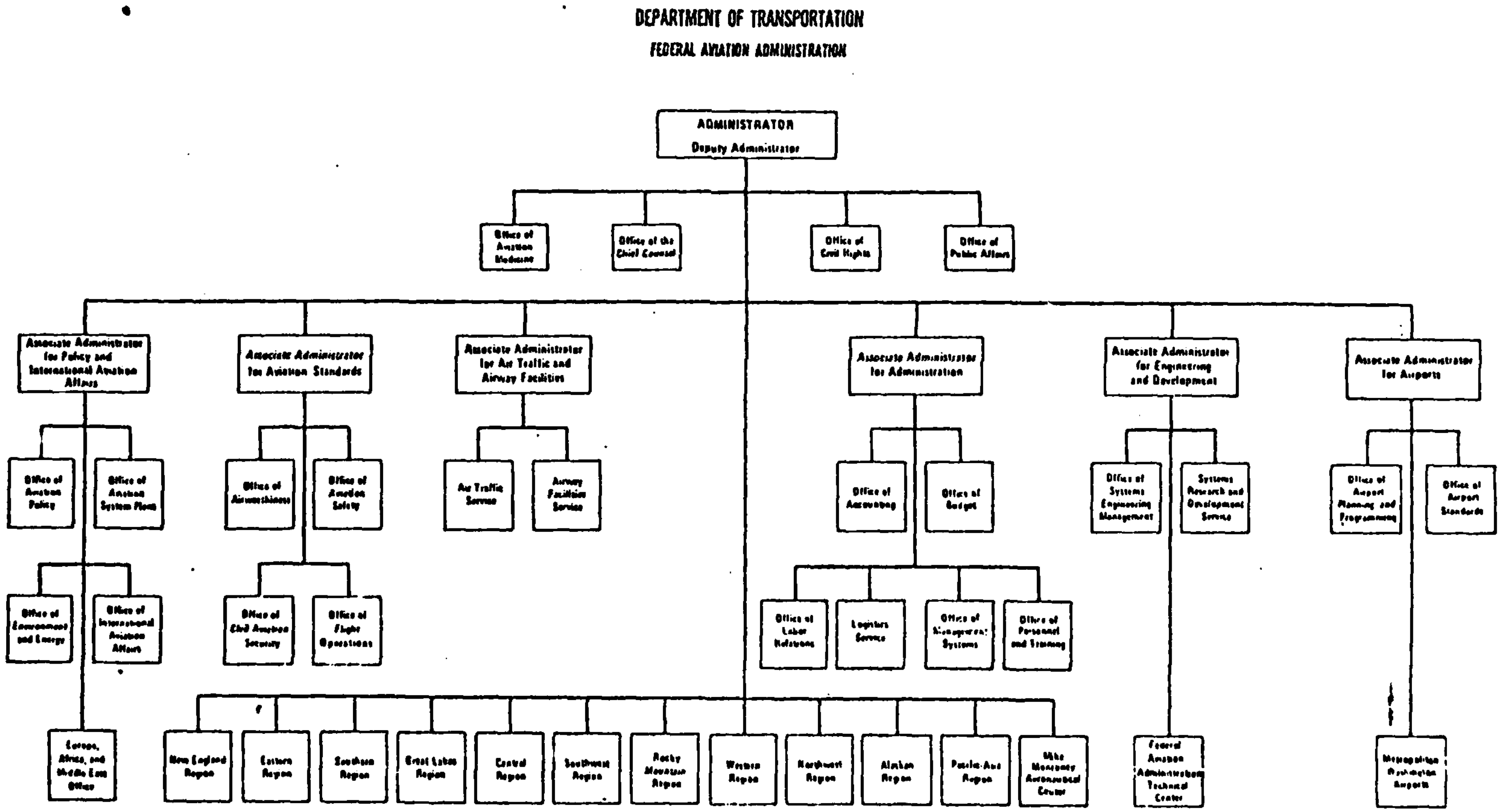

Fig. 2 - Organization of the Federal Aviation Administration

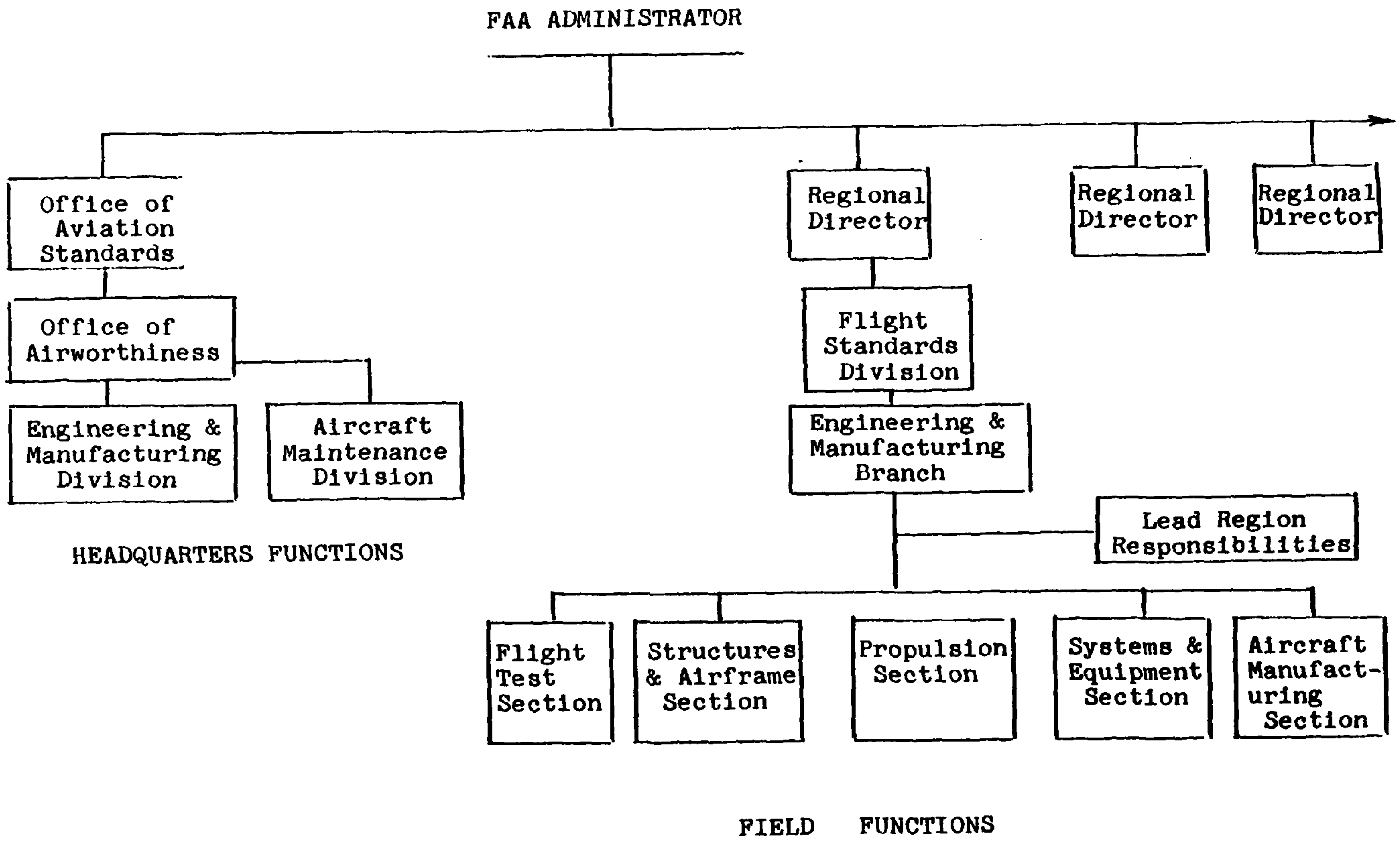

Fig.3- Organization and Management to Maintain Aircraft Safety Standards in Engineering and Manufacturing.

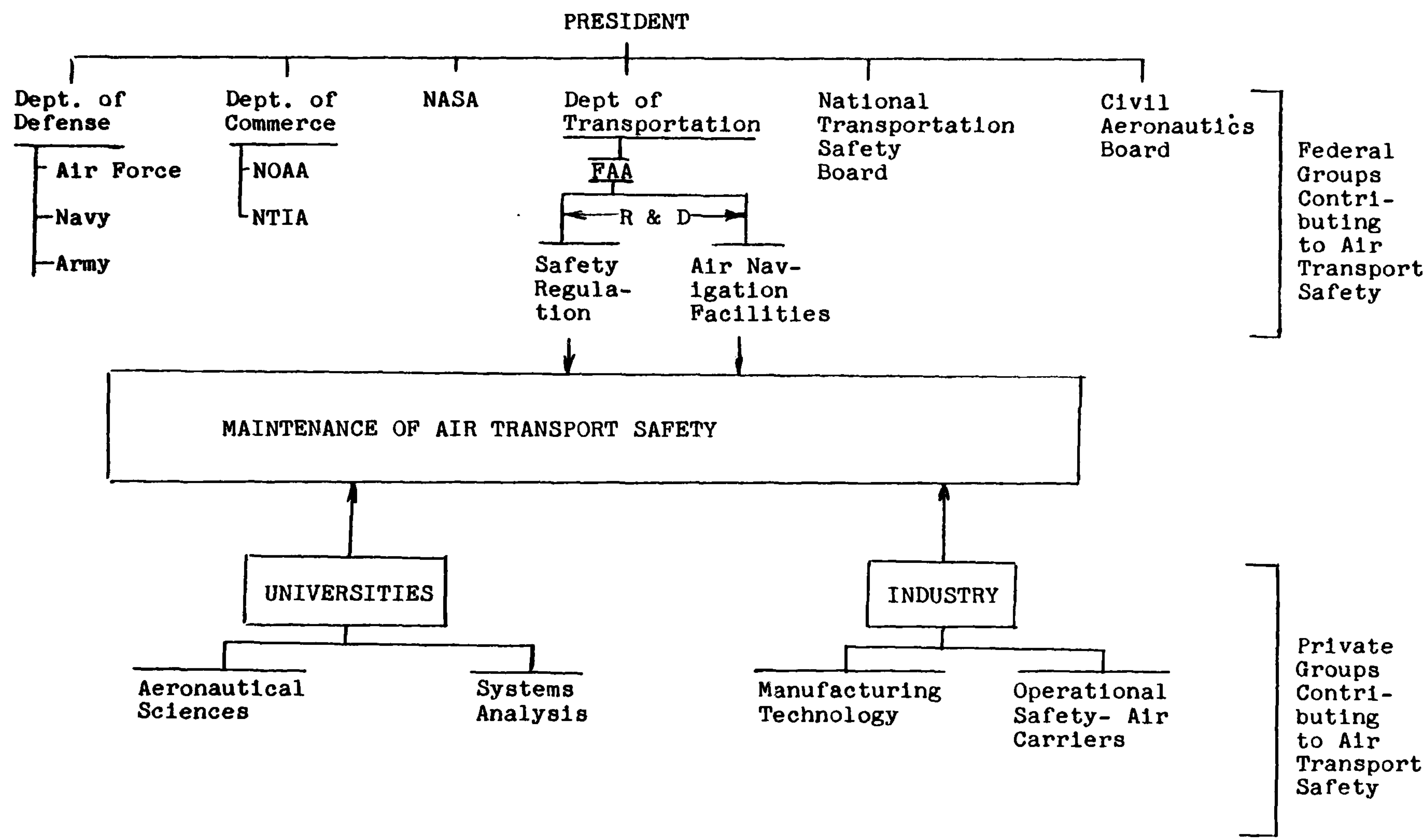

Fig.4- National Contributions to Maintenance of Air Transport Safety.

FIGURE 5

COMPARISON OF FAA BUDGET APPROPRIATIONS WITH ACCIDENT RATE OF U.S. AIR CARRIER

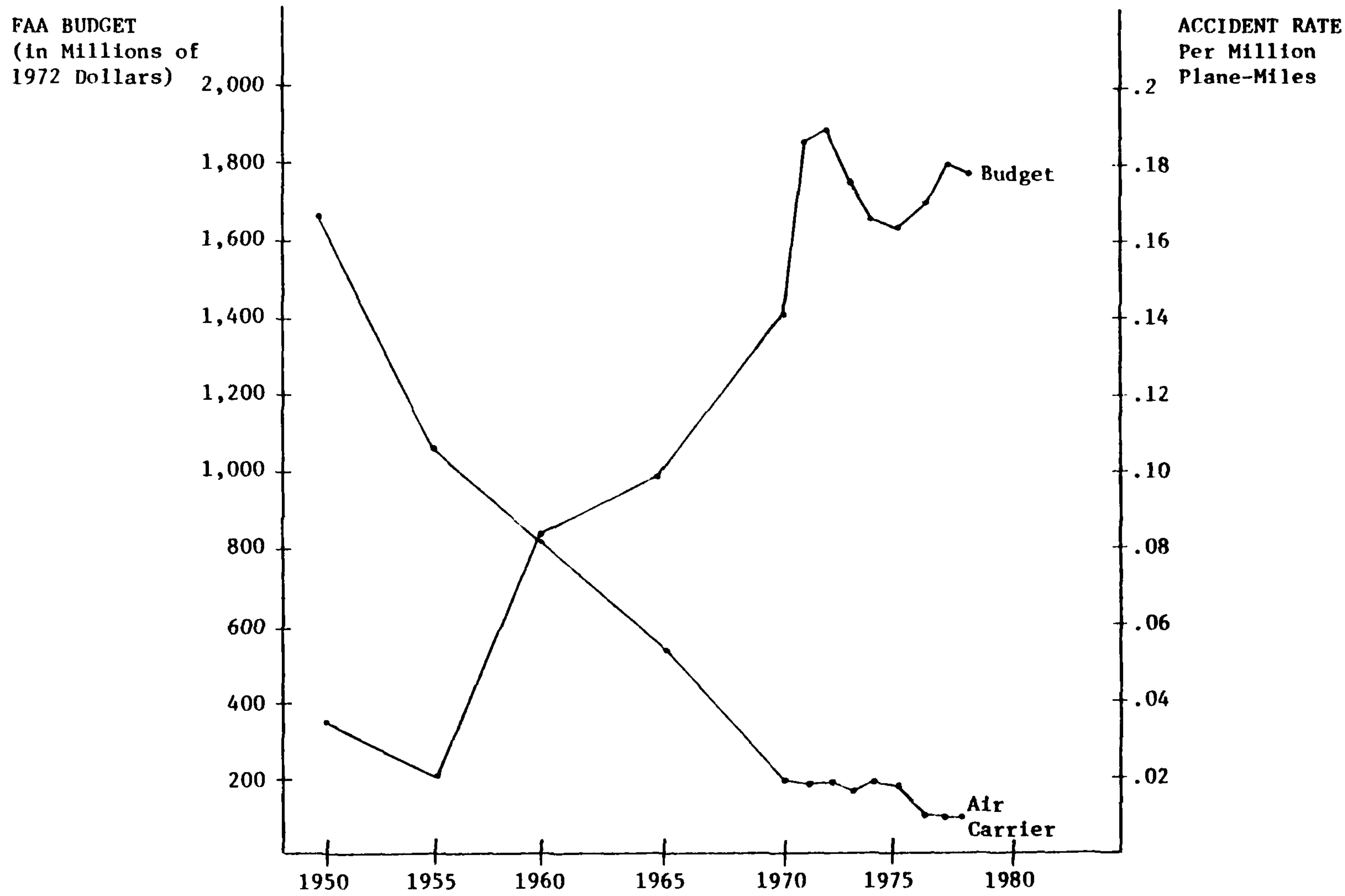

TABLE A

EMPLOYMENT AND BUDGET OF FAA AND PREDECESSORS

Year	Total Personnel	Budget Appropriations*
1927	234	$ 1.64
1930	1,698	19.44
1935	2,685	19.34
1940	4,841	87.60
1945	10,847	89.50
1950	18,045	348.40
1955	15,554	215.80
1960	38,261	834.80
1965	45,350	978.20
1970	51,438	1,408.00
1971	54,515	1,860.00
1972	53,330	1,901.00
1973	53,533	1,750.00
1974	56,486	1,667.00
1975	57,678	1,634.00
1976	58,033	1,700.00
1977	57,994	1,807.00
1978	58,925	1,786.00

* In millions of 1972 dollars

Source: FAA Statistical Handbook of Aviation

TABLE B

ACCIDENT RATES OF U.S. AIR CARRIERS — ALL OPERATIONS*

Year	Accidents	Plane Miles Flown (10^6)	Accident Rate Per Million Plane-Miles
1950	90	536	.167
1955	93	863	.106
1960	90	1,130	.078
1965	83	1,540	.054
1970	55	2,685	.020
1971	48	2,661	.018
1972	50	2,619	.019
1973	43	2,647	.016
1974	47	2,464	.019
1975	45	2,478	.018
1976	28	2,568	.011
1977	26	2,684	.010
1978	24	2,794	.009

* Air Carrier operations include certified route carriers, supplemental carriers and commercial operators of large aircraft.

Source: NTSB Annual Review of Aircraft Accident Data, U.S. Air Carrier.

TABLE C

ACCIDENT RATES OF U.S. GENERAL AVIATION*

Year	Accidents	Plane Miles Flown (10^6)	Accident Rate Per Million Plane-Miles
1950	4,505	1,060	4.2
1955	3,343	1,216	2.7
1960	4,793	1,769	2.7
1965	5,196	2,562	2.03
1970	4,712	3,207	1.47
1971	4,648	3,143	1.48
1972	4,256	3,317	1.28
1973	4,255	3,687	1.15
1974	4,425	3,864	1.14
1975	4,237	3,939	1.08
1976	4,198	4,172	1.00
1977	4,286	4,402	0.97
1978	4,494	4,964	0.90

* General Aviation refers to the operation of U.S. Civil Aircraft owned and operated by persons, corporations, etc. other than those engaged in U.S. air carrier operations.

Source: NTSB Annual Review of Aircraft Accident Data, U.S. General Aviation.

TABLE D

COMPARATIVE SAFETY RATE:

INTER-CITY TRAVEL IN THE UNITED STATES

	Passenger Fatalities Per 100 Million Passenger Miles				Passenger Miles (Millions)	
Year	Auto	Air	Bus	Rail	Total Air, Rail, Bus	Air Per Cent of Total
1940	3.5	3.0	*	0.34	NA	NA
1945	2.9	2.1	0.17	0.16	NA	NA
1950	2.2	1.1	0.17	0.58	55,990	14.21
1955	2.7	0.79	0.19	0.07	60,072	32.86
1960	2.2	0.96	0.11	0.16	62,340	48.8
1965	2.4	0.38	0.23	0.07	88,948	58.3
1970	2.1	0.00	0.02	0.09	135,335	77.0
1971	1.9	0.16	0.08	0.23	141,846	75.0
1972	1.9	0.13	0.17	0.56	152,299	77.6
1973	1.7	0.10	0.17	0.07	162,016	78.0
1974	1.3	0.13	0.06	0.08	167,665	77.4
1975	1.4	0.08	0.02	0.08	166,991	78.8
1976	1.5	0.003	0.01	0.05	180,395	80.5
Ratio of 1976 fatality rate to 1940:	.43	.001	.06	.15		

* Bus included with auto.

Source: U.S. Congress, House of Representatives, Hearings Before a Committee on Government Operations, "Airline Deregulation and Aviation Safety," Washington, D. C., 1977, p. 359.

TABLE E HAZARDOUS MATERIALS INCIDENTS AND ACCODENTS--REPORTED NUMBERS OF I/A

MODAL ADMINISTRATIONS

Modes		FHWA						
Year	FAA	Private Carrier	Common Carrier	FRA	Water	Freight Forwarders	Other	Total
1971	4	224	1,552	343	11	0	121	2,055
1972	33	342	3,558	333	9	0	53	4,328
1973	49	419	5,048	409	12	0	65	6,002
1974	157	361	7,251	616	26	2	15	8,428
1975	152	903	8,988	676	32	6	12	10,769
1976	90	549	10,223	982	13	11	21	11,889
1977	106	547	16,000 a	899	12	10	19	17,593
1978	231	565	15,983	1,091	47	5	0	18,022
TOTAL	822	3,910	59,348	5,449	162	34	376	79,286

a A partial listing not including incidents/accidents less than $1,000 was available and totaled 6,745 (the only breakout of this type available).

Source: Clyde Klintstiver (202) 472-1024, U.S. Department of Transportation. Washington, D.C.

TABLE F HAZARDOUS MATERIALS PROPERTY DAMAGE--REPORTED (DOLLARS)

MODAL ADMINISTRATIONS

Modes Year	FAA	FHWA Private Carrier	Common Carrier	FRA	Water	Freight Forwarders	Other	Total
1971	$ 0	$ 1,661,475	$ 3,118,508	$ 1,491,745	$ 201,052	$ 0	$136,005	$ 6,608,785
1972	2,850	2,701,366	3,507,379	1,549,358	1,252,095	0	223,925	9,316,973
1973	5,104	1,713,815	2,604,163	3,021,685	8,009	0	14,439	7,367,215
1974	4,511,708	924,980	3,849,136	11,965,143	20,117	0	13,035	21,284,119
1975	9,159	2,574,211	3,028,405	1,481,995	6,331	3,345	182	7,103,898
1976	20,512	2,057,017	3,617,548	2,294,633	5,270	405	3,788	7,999,173
1977	28,686	4,356,545	4,272,106	7,815,243	18,258	351	9,700	16,500,889
1978	6,834	3,819,373	5,442,533	6,848,364	17,912	160	0	16,135,176
TOTAL	$4,584,853	$19,808,782	$29,519,818	$36,468,166	$1,529,044	$4,261	$401,074	$92,315,998

Note: The damage figures are from the preliminary reports. Later reports, in those instances where they became available, have shown losses from three to ten times the amount of first reports.

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